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J. W. L. GLAISHER, M.A., F.R.S., President, in the Chair.

Captain Robert Dowling, Denmark House, Queen's Terrace, Southampton;

Rev. Robert Sparke Hutchings, Alderbury Vicarage, Salisbury;

Rev. Harry Pool Slade, Tow Law, Darlington; and

Washington Teasdale, Rosehurst, Headingley, Leeds;

were balloted for and duly elected Fellows of the Society.

On Hartwig's Nova Andromedæ. By Ralph Copeland, Ph.D.

On September 1, 1885, a telegram arrived at Dun Echt Observatory, which had been sent from Kiel by Prof. Krueger at 12 o'clock on the previous night. It ran: "Variation in *Andromeda* nebula found by Dr. Hartwig, starlike nucleus; please look for it." Dun Echt Circular, No. 97, to this effect was forthwith circulated, and preparations were made for examining the nebula.

The night was not very favourable, but with the 6-inch Simms' telescope and a power of only 28, it was seen that the centre of the great nebula was occupied by an object "exactly like a star; yellowish in colour." It was estimated of the $7\frac{1}{2}$ magnitude, but respecting this and other estimations with a very low power see the remarks further on. Viewed through a prism, held between the eye and the eyepiece, the first glance

showed that the spectrum had little or nothing in common with the brilliant spectrum of Schmidt's *Nova Cygni* in its earlier stages. The spectrum was continuous from end to end, and only on close examination could slight condensations indicative of bright lines be detected. The spectrum was not considered to differ strikingly from that of the nebula.

September 2 was cloudy, but a clear interval shortly after midnight on the 3rd enabled Lord Crawford and the writer to examine the *Nova* critically with the 15-inch Equatorial; it was then seen that following the new star, a little to the north, was a nebulous object. Naturally concluding that this might be the nucleus of the Great Nebula, the relative position of the objects was measured with the micrometer, and they were also connected with an $11\frac{1}{2}$ magnitude star some $9\frac{1}{2}$ seconds preceding. On comparing the interval between this latter star and the nebula with a rough measure taken at Birr Castle on October 25, 1851, it was possible to announce on September 5, in Circular 98, "that the *Nova* is most probably situated some $1^{s}.6$ preceding, and $5''$ south of the old nucleus, which is much overpowered by the light of the star." To test this conclusion the measurements were repeated from time to time as occasion offered, the place of *Nova* being at the same time determined with the Transit Circle. The following is a summary of the results for each night:—

1. Nebular Nucleus to $11\frac{1}{2}^m$ star preceding.

Date. 1885.		Measured. Position-Angle.	Derived. Distance.	$\Delta\alpha$	$\Delta\delta$	No. of Measures.	Observer.
		° ′	″	s	″		
Sept. 5		... ...	124·65	...	...	2	R. C.
17		261 3	124·98	−10·846	−19·44	6	,,
1885·71	Mean	261 3 ± 5′·3	124·90 ± 0″·29	−10·839 ± 0ˢ·025	−19·43 ± 0″·20		

2. *Nova* to $11\frac{1}{2}^m$ star preceding.

Sept. 3		261 41	109·97	−9·559	−15·91	2	,,
9		262 7	109·73	−9·549	−15·05	4	,,
17		262 14	110·26	−9·598	−14·90	6	,,
1885·70	Mean	262 7 ± 12′·6	110·04 ± 0″·24	−9·575 ± 0ˢ·021	−15″·12 ± 0″·40	12	

3. *Nova* to nebula nucleus.

Sept. 3		73 16	18·81	+1·582	+ 5·42	1	,,
9		73 20	16·11	+1·356	+ 4·62	2	L. B.
12		75 5	16·18	+1·374	+ 4·16	2	R. C.
19		73 53	16·62	+1·403	+ 4·61	6	,,
Dec. 2		74 41	16·65	+1·411	+ 4·40	8	,,
1885·79	Mean	74 15 ± 21′·6	16·65 ± 0″·26	+1·408 ± 0ˢ·022	+ 4·52 + 0″·12	19	

4. *Nova* to 13^m star.

Oct. 2		172 9	157·05	+1·884	−155·28	2	,,

5. *Nova* to 11^m star.

Oct. 2		156 53	231·01	+7·977	−212·46	2	,,

Meridian Observations of Nova Andromedæ with the 8-inch Transit Circle.

1885.	Apparent α h m s	Red. s	Apparent δ. ° ′ ″	Red. ″	Observer.
Sept. 3	0 36 30·86	−4·11	+40 38 24·8	−10·4	L. B.
10	30·85	−4·23	...	...	„
15	31·10	−4·30	28·6	−14·8	„
19	31·06	−4·35	29·4	−15·9	„
25	31·11	−4·42	30·5	−17·7	„

Mean Equinox 1885·0.

1885.	α h m s	δ ° ′ ″
Sept. 3	0 36 26·75	+40 38 14·4
10	26·62	...
15	26·80	13·8
19	26·71	13·5
25	26·69	12·8

on the mean of which is based the following table :—

Mean Places 1885·0. (*Berliner Jahrbuch.*)

	α h m s	δ ° ′ ″
11½ mag. star	0 36 17·14	+40 37 58·5
Nova Andr.	0 36 26·71	+40 38 13·6
Neb. nucleus	0 36 28·08	+40 38 18·1
13 mag. star	0 36 28·59	+40 35 38·0
11 mag. star	0 36 34·69	+40 34 41·1

Observers: L. B. = Dr. Ludwig Becker; R. C. = Ralph Copeland.

The mean errors of the micrometrical measures are derived from a comparison of the original readings.

The relative position of the nucleus of the Great Nebula and the 11½-magnitude star preceding is shown directly in 1; but it also results from the sum of 2 and 3, which give

	$\Delta\alpha$	$\Delta\delta$
$11\frac{1}{2}^m$ star to nebula	$-10^s{\cdot}983 \pm 0^s{\cdot}030$	$-19''{\cdot}64 \pm 0''{\cdot}42$

which combined with 1 affords the mean value

	$\Delta\alpha$	$\Delta\delta$
$11\frac{1}{2}^m$ star to nebula	$-10^s{\cdot}898 \pm 0^s{\cdot}019$	$-19''{\cdot}47 \pm 0''{\cdot}18$

These quantities having been more frequently measured at various observatories than any other feature connected with the

nebula, the earlier observations are here collected and brought up to 1885·0.

	Pos.	Precession.	Distance.	$\Delta\alpha$ 1885·0.	$\Delta\delta$
	° ′	′	″	s	″
Lamont,* 1836, Oct. 13 and 14	81 12·2	+3·3	125·24	−10·883	−19·05
O. Struve,† 1847 to 1864, 10 nights, 1850·97 ...	81 26	+2·4	125·13	−10·871	−18·55
Lord Rosse,‡ 1851, Oct. 25	83	+2·3		−10·639	−14·79
D'Arrest,§ 1863, Aug. 12 $\Delta\alpha = -11^{s}\cdot26$				−11·28	
1865, July 30 $\Delta\alpha = -11^{s}\cdot60$				−11·62	
H. Vogel,‖ 1866, Oct. 19 $\Delta\alpha = -10^{s}\cdot79$, $\Delta\delta = -19''\cdot4$		+1·3		−10·807	−19·35

Of these results those by Lord Rosse and D'Arrest, from the nature of the apparatus employed, are much less accurate than the others. The remaining observations, although somewhat discordant, show a great relative fixity in the two objects, the $\Delta\delta$ alone indicating a slight possibility of progressive change.

The Spectrum.

As will be seen further on, the New Star was of about the $8\frac{1}{2}$ magnitude when first observed at Dun Echt on Sept. 1, 1885. It was therefore *a priori* fairly within range of the spectroscope; the weather, however, only permitted a brief examination, chiefly by looking through a prism into the eyepiece, with the results already mentioned, that the spectrum was continuous, with feeble traces of bright lines, and much resembled that of the Great Nebula. The star was "yellowish" in colour on this night, and "full yellow" on Sept. 3. It was not until the 10th that a settled fine night permitted a close spectroscopic examination. With the unmagnified dispersion of a direct-vision Vogel spectroscope the spectrum extended from W.L. 670^{mmm} to 453^{mmm}, or from between B and C to half-way between F and G. When the spectrum was sufficiently narrow all the colours were visible, with a suspicion of brighter points in the line. An attempt was made to measure these with the Grubb spectroscope and a flint prism of only 40° refracting angle. This instrumental change cut down the spectrum to the limits of 600^{mmm} and 456^{mmm}, with a maximum at $544\cdot4^{mmm}$ and "a suspicion of a bright line, but hardly more," at $482\cdot2^{mmm}$. With the same apparatus the spectrum appeared *quite continuous* on Sept. 11, but again showed traces of bands on the 13th, and was slightly banded on the 15th. Traces of a condensation of light were seen at W.L. $471\cdot6^{mmm}$ on Sept. 20.

* *Annalen der K. Sternwarte, München*, vol. xxxii. (1869), p. 306.
† *Mélanges Mathématiques et Astronomiques*, vol. iii. p. 571.
‡ *Phil. Trans.*, 1861, p. 709. § *Siderum Nebulosorum Obs.*
‖ *Beobachtungen von Nebelflecken*, &c., Leipzig, 1867, p. 65.

By the end of September a special acute prism of only 15° angle was received from Mr. Hilger. This had been made with a view to obtaining a very short and relatively bright spectrum, in which it might be possible to measure the positions of the brighter bands. But by this time *Nova* had fallen to about 9·8 magnitude, so that, in spite of the very low dispersion, only traces of two brighter points towards the yellow end of the spectrum could be made out on September 30, the rest of the spectrum appearing absolutely continuous. On October 1, by taking every precaution in the way of moderating the illumination, and protecting the eyes from all extraneous light with a black cloth, these two lines and a still fainter one were measured with a power of 7 on the viewing telescope. The measures and wave-lengths are:—

	Screw. r p	W.L. mmm.	Means. mmm.
Band 1	52 25·7	557·1	546·8
	4·9	541·8	
	4·6	541·5	
Band 2	51 54·3	510·1	514·0
	69·4	519·5	
	58·1	512·4	
Band 3	51 23·1	493·1	489·2
	16·9	489·9	
	5·8	484·5	
Red end	52 48·7	575·8	575·8
Violet end	50 67·2	467·6	467·6

Respecting the discordancy of these measures it must be noted that, since one revolution of the tangent-screw covers 10′ of arc, the whole visible spectrum was but slightly more than 18′ in length; the measures for the three bands, therefore, range over 2′·1, 1′·5, and 1′·7 respectively, arcs which cannot be considered excessive for so low a power as 7 diameters, on such ill-defined objects. Indeed, the task of measuring these feeble bands might fairly be compared with that of attempting to fix the azimuths of three terrestrial objects in dim twilight with a theodolite of which the telescope magnified seven times. Part of the inaccuracy is also probably due to the indeterminateness of the bands themselves.

Making due allowance for this uncertainty, it seems probable that the three "bright" bands of wave-lengths, 546·8, 514·0, and 489·2, are identical with the three brightest bands afterwards measured with the same apparatus in Mr. Gore's *Nova Orionis*, of which the brightest parts were at wave-lengths 542·8, 516·2, and 494·4.* The trace of a condensation of light at W.L. 471·6

* *Monthly Notices*, vol. xlvi. p. 110.

seen on September 20 agrees well with the bright line in *Nova Orionis* at W.L. 472·2; while the maximum of light in *Nova Andromedæ* at 544·4 on September 10 is closely in accord with that for the star in Orion at 542·8. The only really discordant item is the point laid down at 482·2 on September 10, which does not correspond to any known bright band in the spectra of variable stars; it was, however, entered in the note-book, in the terms already stated, as "a suspicion of a bright line, but hardly more." But if it does roughly represent the position of a "bright" line actually visible in the spectroscope, one would feel inclined to regard it as a trace of the F line.* On October 2 the spectrum presented the same appearance as on the preceding day. On October 19 it could be still noted as continuous, but not uniform, with the Vogel spectroscope.

Although the foregoing results differ widely from those obtained at Greenwich, and also at Yale College, as regards the three chief lines the observer cannot doubt as to their general correctness. The spectroscope was specially adapted to the work, the average thickness of the prism traversed by the light being less than $\frac{5}{16}$inch, and the object-glasses of collimator and viewer were cemented so as to reduce the loss of light to a minimum. The arrangement of the tangent-screw is also such that the observer has the least possible idea as to the position of the lines measured until the divided head is read off. *E.g.*, in this particular instance of October 1, until the observations were ended, the observer had not the slightest suspicion that the "red" end of the spectrum was actually above the D lines. Besides, in the case of an object losing so rapidly its power of emitting light, it is quite possible that the spectrum may have slightly varied from day to day.

In conclusion, it seems worthy of remark that the spectrum described above is the same as that given by any ordinary hydro-carbon flame, burning so feebly that the spectrum of the blue base of the flame is just beginning to show through the continuous spectrum afforded by the white part of the flame.

Estimations of Magnitude.

The earlier estimations were made either with the 6-inch Simms' telescope, power 28, or with a power of 24 on either of the two $3\frac{3}{4}$-inch finders of the 15-inch Equatorial. But about September 10 it was found that these low powers showed the new star relatively much brighter than did the large telescope, and a greater amplification. On trial it was found that this was because the low powers failed to separate the star sufficiently from the surrounding nebulosity; the image, therefore, which was

* According to *Nature*, No. 837, p. 42, Mr. O. T. Sherman, of Yale College Observatory, has seen the bright F line in the spectrum of the Great Andromeda Nebula.

compared with the neighbouring stars was made up of *Nova plus* the denser part of the nebula. In the 15-inch, on the other hand, *Nova's* image was not only quite distinct from that of the nebular nucleus, but the remainder of the nebula could be almost completely effaced by a suitable illumination of the field of view. Experimenting in this way on September 10, it turned out that *Nova* seen with a high power in a bright red field was of the 8·7 magnitude by comparison with neighbouring stars, or relatively $0^{m}\cdot8$ fainter than when seen in the finder or the 6-inch, which showed it of the 7·9 magnitude. From this it would seem that the low powers and dark field included as much of the surrounding nebulosity along with *Nova* as would be equal to a star of the 8·6 magnitude; for on Pogson's scale

Light of $8^{m}\cdot7$ star + light of $8^{m}\cdot6$ star = light of $7^{m}\cdot9$ star, nearly.

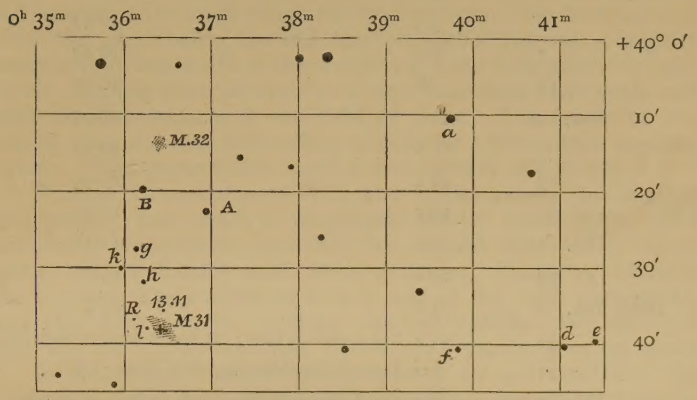
After this date, therefore, all the comparisons were made in a field bright enough to efface the diffused nebulosity, or, when the new star became fainter, with as much light as it would bear. The estimations were made on an arbitrary scale, of which it was found that $0^{m}\cdot8$, or rather $0^{m}\cdot79$, corresponded to one magnitude of Argelander's scale. The following is a list of all the stars used in direct comparison with *Nova* or the nucleus, or for fixing the scale of magnitudes; in particular A and B were used in checking the brightness of *g*, *h*, and *k*. The places are in part brought up from the *Durchmusterung*.*

	α (1885·0) h m s	δ (1885·0) ° ′	No. in D.M.	In D.M.	Magnitude Adopted.
k	0 35 55·5	+40 30·4			11·60
R	0 36 7·9	40 37·1			(13 ±)
g	0 36 9·7	40 27·8			10·63
B	0 36 12·8	40 19·7	+40,145	9·0	9·1
h	0 36 14·9	40 32·3			10·95
l	0 36 17·1	40 38·0			11·60
A	0 36 57·9	40 22·8	+40,149	9·1	9·0
a	0 39 44·6	40 10·7	+40,158	7·5	7·60
f	0 39 49·2	40 40·8	+40,159	9·5	9·42
d	0 41 2·3	40 40·3	+40,161	9·1	9·01
e	0 41 25·1	40 39·8	+40,162	9·1	9·18

The subjoined sketch contains all the D.M. stars near the

* R is a small star measured at Birr Castle on October 28, 1851, which, according to M. Trouvelot (*Comptes Rendus*, tome ci. p. 799), was not visible at Harvard College in 1874. It is at present (1886, December 6) of the 13th magnitude, and about equal to star 13, which is also wanting in M. Trouvelot's drawing. R appears as a comparatively bright star in the reproduction of Mr. Common's photograph in *Nature*, No. 831, which, however, does not give 13.

Great Nebula as well as those of the foregoing list, and the two small stars, 11 and 13, measured on October 2, 1885.



Stars near the Great Nebula in Andromeda: Epoch 1885·0
+ = Nova Andromedæ.

The stars *g*, B, *h*, *l*, and A are respectively identical with *a*, B, *β*, *γ*, and A of Mr. Stone's list in *Monthly Notices*, vol. xlvi. p. 57, but the magnitudes differ considerably towards the fainter end of the scale; *e.g.*, Mr. Stone's *β*, which is called $11^{m}\cdot4$ at Oxford, is barely $11^{m}\cdot0$ on the Dun Echt scale.

The following table shows the resulting magnitude of *Nova* for each night on which estimations were made:—

Date.	G.M.T.	Estimations with finder and 6-inch.	Magnitude.
	h	m	m
1885, Sept. 1	8·9	7·68	[8·47]
3	12·5	7·76	[8·55]
5	13·2	7·84	[8·63]
9	12·5	7·92	[8·71]
10	10·2	7·92	[8·71]
11	12·0		8·85
12	9·2		8·97
13	...		8·77
15	...		9·17
17	...		9·49
19	9·3		9·41
29	11·6		9·75
30	...		9·83
Oct. 2	12·9		9·91
4	10·3		10·39

Date.	G.M.T. h	Estimations with finder and 6-inch. m	Magnitude. m
1885, Oct. 5	13·5		10·47
6	7·3		10·47
7	7·2		10·47
19	7·8		10·91
Nov. 4	11·2		10·95
5	11·8		10·95
7	12·1		10·95
30	10·1		11·9
Dec. 2	9·2		12·1*
29	10·1		13·0
1886, Jan. 2	9·1		13·5
30	11·2	Not certainly seen; $7\frac{1}{4}$ hours west of meridian.	
31	7·0	Just discernible; sky very clear ·14^m ± .	
Feb. 2	8·0	Not a trace of *Nova* with 15-inch aperture.	

These observations, plotted by themselves on cross-lined paper, would lead to the conclusion that *Nova* decreased continually but very irregularly, the light curve falling by a succession of steps. But on a comparison with the results of the eye-estimations at the Radcliffe Observatory, and the photometric results of Prof. Pritchard, M. Charlier, and Dr. Müller, this conclusion is not confirmed, the irregularities disappearing from the mean of all the observations. Even the very slow decrease between September 5 and 13, although confirmed by Dr. Hartwig's curve in *Ast. Nach.*, No. 2690, is not apparent in the mean of the other observations. The records agree best in showing that the star faded more rapidly at first than in the later stages of its disappearance.

The Visibility of the Nebula.

It has already been said that the nucleus of the Great Nebula was seen and measured on September 3. It was not seen on September 1, but there was so much cloud, and attention was so completely directed to the new star and its spectrum, that the relatively faint nucleus may have been simply overlooked, the more so as the greater brilliancy of *Nova* on that night must have overpowered it still more than on the 3rd. From the moment the nebular nucleus was discerned a look-out was naturally kept for the remaining features of the nebula. By September 10 a decrease of two or three tenths of a magnitude in *Nova* already permitted the innermost of Bond's dark lanes to be made out, the remoter parts of the nebula at the same time presenting their usual appearance. With power 307 the nucleus was estimated as 2″ in diam.=11^m star; very sud-

* In dark field *Nova* about equal to the nucleus of the nebula, but a red field obliterates the nucleus, leaving *Nova* still clearly visible.

denly much brighter in the middle. With power 132 it was more gradually brighter in the middle. On October 5, with power 132, the nebula was splendidly visible, apparently as the observer had known it for more than twenty-five years. On November 5, 1885, the night being fine and the moon out of the way, a lengthy examination was made of the nucleus and the new star with eyepieces ranging from about 120 to 600 diameters, both with and without illumination of the field of view. The lenses of the lowest eyepiece are adjustable, so that its power varies to some extent. The appearances may be summarised as follows :—

Without Illumination.—With the lowest power the nucleus was stellar, and about 1 magnitude fainter than *Nova*. The nebulosity everywhere extended far beyond the field of view, except where Bond's dark lanes came in. Power 132 showed the nucleus barely different from a star of the 11th magnitude, and also with 229 the nucleus was fairly stellar, but with 307 this was no longer the case, the densest part appearing about 4″ in diameter. Increasing the power to 442 rendered the nucleus slightly more diffuse, and showed an elongation towards *Nova*. With this eyepiece *Nova* was still as sharp and distinct as any other star. Magnified about 600 times the nucleus was seen as a soft nebulosity 5″ in diameter.

With bright Illumination of the Field.—With a red field sufficiently bright to restrict the visible nebulosity to about 20″ diameter, the nucleus appeared quite stellar and one magnitude fainter than *Nova*. This was with the lowest eyepiece. Tried in the same way with powers 132 and 229 the nucleus did not appear nearly so star-like, and on increasing the illumination it almost disappeared, while *Nova* remained quite bright. With power 307, the red illumination not being quite strong enough to obliterate the nucleus, a bright yellow field was tried which completely overpowered the nucleus, while leaving the new star brightly visible. On applying power 442 with the same field, the nucleus appeared 4″ or 5″ in diameter, but was very sensitive to illumination, being extremely difficult to distinguish even when *Nova* was quite bright. With a power of 600 it was found that the nucleus disappeared before the star 11^s preceding.

The chief points believed to be shown by these experiments are :—the perfectly stellar character of *Nova* and the extreme sensitiveness of the Great Nebula and its nucleus to illumination. It therefore seems but reasonable to conclude that the invisibility of the nebula, and even of the nucleus, on September 1 was solely due to the overpowering light of the new star.

To test this point still further, a Zöllner's photometer was attached to the 15-inch on November 20 of this year. On contracting the aperture to 3·6 inches it was found that the *Durchmusterung* star + 40° 158, 7·5 magnitude, could be most perfectly counterfeited by the artificial star of the photometer. On bringing this artificial star in front of the Great Nebula, the nucleus gradually disappeared as the artificial star approached it. In point of fact, the nucleus of the Great Nebula required

the artificial star to be fully 75″ distant before becoming fairly defined. On the other hand the companion nebula, M. 32, bore the comparison star very much closer, say within 15″. Dr. L. Becker fully confirmed this experiment, which was repeated by recurring three times to the D.M. star. When the artificial star was placed exactly upon the nucleus it was surrounded by a soft nebulosity, without any distinctive features. This experiment seems conclusive as to the power of a $7\frac{1}{2}$-magnitude star to completely obscure every trace of the central part of the Great Nebula in *Andromeda* without necessarily effecting any change in the nebula itself.* At the same time, it does not at all prove that no change took place in the nebula, but simply that it was impossible to observe any such change as long as the star was shining brightly. At Dun Echt, however, no traces of a permanent change brought about by the outburst of the new star have been detected in the nebula since the fading of the star. Nevertheless, the fact of the appearance of a similar star in the globular cluster M. 80 = G. C. 4173 = *h.* 3624, as observed by Prof. Auwers and Mr. Pogson in 1860, goes far towards showing a connection between these sudden outbreaks and their apparent surroundings. This was pointed out by the late C. G. Talmage at the conclusion of the reading of a Paper on the New Star at the meeting of the British Association at Aberdeen in September 1885, and also forms the subject of a communication to the *Astronomische Nachrichten* (No. 2715)† by Prof. Auwers. The spectrum of G. C. 4173, moreover, is known to be very faint and continuous from the observations of Lieut.-Col. Herschel in 1868 (see *Proc. Roy. Soc.*, vol. xvi. p. 453), and thus resembles that of the Great Nebula in *Andromeda*. The chief difference between the two nebulæ is that, while Sir J. Herschel's 20-foot telescope completely resolved G. C. 4173 on two occasions at the Cape of Good Hope, the great northern nebula has never shown more than very doubtful signs of resolvability. It may be remarked that the decadence of the *Nova* of 1860 was much more rapid than that of the recent star, for Prof. Auwers' figures show that it fell 3 magnitudes in about twenty days, while *Nova Andromedæ* required about eighty days to decrease to the same extent.

With regard to the reported occurrence of a fresh stellar outbreak in the nebula this autumn (*Astr. Nach.* No. 2755), it may be worth recording that M. 32 was very carefully examined on September 27, without anything being seen in the Great Nebula that appeared worthy of remark. On October 20, the

* It has since occurred to the writer that by using the electric light it may be possible to produce an artificial star sufficiently bright to permit of repeating this experiment with the full aperture of a 15-inch telescope. By a close reproduction of the appearance of the star and the nucleus as observed on September 3, 1885, the brightness of the star on that day may even yet be redetermined with some approach to accuracy, on the probable assumption that the nucleus has not changed.

† See also *Ast. Nach.* vol. liii. col. 293; vol. lviii. col. 374; and *Monthly Notices*, vol. xxi. p. 32

distance of the nucleus from the small star so often mentioned was 125″·16, as a result of six settings; nor could a trace of anything, except the old nucleus, be seen near the centre of the nebulosity, with a power of 229 on the 15-inch. The nebula was also swept over with the 6-inch object-glass prism on October 22, when nothing was seen in the diffused image to indicate the presence of a star.

Dun Echt Observatory:
1886, *Dec.* 7.

Formulæ for Binary Stars. By J. E. Gore.

For the following binary stars, of which the observations are not yet sufficient for the calculation of a satisfactory orbit, I have computed, by the method of least squares, the following empirical formulæ for the calculation of an ephemeris. The positions of the stars are for 1880·0:—

Σ 3116.

R.A. $6^h\ 15^m{\cdot}9$, $-11°\ 42'$.

Magnitudes 6·2 and 10.

$\theta = 21°{\cdot}89 + 0°{\cdot}1425\ (t-1850)$.

$\rho = 4''{\cdot}14 - 0''{\cdot}018\ (t-1850)$.

45 Geminorum = OΣ 165.

R.A. $7^h\ 1^m{\cdot}5$, $+16°\ 8'$.

Magnitudes 5, 10·7.

$\theta = 127°{\cdot}72 - 1°{\cdot}585\ (t-1850) - 0°{\cdot}00811\ (t-1850)^2$.

$\rho = 3''{\cdot}697 - 0''{\cdot}0434\ (t-1850)$.

9 Argûs = Burnham 101.

R.A. $7^h\ 46^m\ 13^s$, $-13°\ 35'$.

Magnitudes 5, 7.

$\theta = 291°{\cdot}38 + 3°{\cdot}044\ (t-1875)$.

$\rho = 0''{\cdot}517$ (1875).

Σ 1175.

R.A. $7^h\ 56^m{\cdot}1$, $+4°\ 30'$.

Magnitudes 7·8, 9·7.

$\theta = 211°{\cdot}16 + 0°{\cdot}369\ (t-1850)$.

$\rho = 1''{\cdot}949$ (1850).

Σ 1287.

R.A. $8^h\ 44^m{\cdot}9$, $+12°\ 35'$.

Magnitudes 8, 10·3.

$\theta = 100°{\cdot}83 - 0°{\cdot}442\ (t-1850)$.

$\rho = 1''{\cdot}675 + 0''{\cdot}013\ (t-1850)$.

Σ 1389.

R.A. $9^h\ 45^m{\cdot}5$, $+27°\ 33'$.

Magnitudes 8, 9.

$\theta = 321°{\cdot}87 - 0°{\cdot}378\ (t - 1850)$.

$\rho = 1''{\cdot}86 + 0''{\cdot}0097\ (t - 1850)$.

OΣ 215.

R.A. $10^h\ 9^m{\cdot}7$, $+18°\ 20'$.

Magnitudes 7, 7·2.

$\theta = 255°{\cdot}60 - 1°{\cdot}103\ (t - 1850)$.

$\rho = 0''{\cdot}445 + 0''{\cdot}0116\ (t - 1850)$.

Σ 1879.

R.A. $14^h\ 40^m{\cdot}4$, $+10°\ 10'$.

Magnitudes 7·8, 8·8.

$\theta = 54°{\cdot}64 - 0°{\cdot}522\ (t - 1850)$.

$\rho = 0''{\cdot}716$ (1850).

Anon. Herculis = Gledhill 528.

R.A. $16^h\ 40^m{\cdot}3$, $+43°\ 42'$.

Magnitudes 8, 8.

$\theta = 132°{\cdot}93 - 2°{\cdot}441\ (t - 1870)$.

$\rho = 0''{\cdot}957$ (1870) (distance diminishing).

Σ 2536.

R.A. $19^h\ 26^m\ 16^s$, $+17°\ 32'$.

Magnitudes 8, 11.

$\theta = 45°{\cdot}29 + 0°{\cdot}761\ (t - 1850)$.

$\rho = 1''{\cdot}852$.

OΣ 437.

R.A. $21^h\ 15^m{\cdot}9$, $+31°\ 56'$.

Magnitudes 7, 10·5 (6·5, 7·2 Perrotin, 1885·720).

$\theta = 62°{\cdot}53 - 0°{\cdot}434\ (t - 1850)$.

$\rho = 1''{\cdot}34$ (1850) ($1''{\cdot}600$ Perrotin, 1885·720).

72 Pegasi = Burnham 720.

R.A. $23^h\ 28^m$, $+30°\ 40'$.

Magnitudes 6, 6·1.

$\theta = 310°{\cdot}98 + 2°{\cdot}229\ (t - 1880)$.

$\rho = 0''{\cdot}404$ (1880).

Formulæ for most of the other binary stars, computed by Drs. Doberck and Dunér, will be found in Gledhill's *Handbook of Double Stars*, and the "Corrections, Notes, &c.," to this excellent work.

Mr. Sherman's Observations of Bright Lines in Stellar Spectra.

By E. W. Maunder.

I fear, from Mr. Sherman's reply to my former Paper, that I was not sufficiently explicit in my criticism of his observations, for he certainly seems to have missed the point of my remarks. Nor has he yet explained his method of procedure in such a way that I can understand it.

His object is "to render the image of the bright line light as broad and intense as may be, and the intensity of the background light a minimum." I see but one way of attaining this end: viz., by employing as high a dispersion as the star will bear, and by making the spectrum as pure as possible by the use of a long collimator and narrow slit. Mr. Sherman has indeed employed a fairly high dispersion, but so far as I can judge has made no effort to secure purity of spectrum.

We may take it that the image of a star in the primary focus of a telescope is practically a point. The spectrum of a star is therefore a straight line, and as the image of the star has no very appreciable breadth it is not necessary, in order to see the spectrum, to use a slit. The star will, as Mr. Sherman truly argues, act as a slit for itself. If, then, certain radiations be missing in the star's light we shall have the coloured line of the star spectrum broken by dark points, each dark point being a negative image of the star. If certain radiations in the star's light be exceedingly brilliant we shall have them appearing as bright points on the coloured line of the star spectrum, each bright point being an image of the star; and indeed the entire continuous spectrum is but a succession of an infinite number of various coloured images of the star. By what means then does Mr. Sherman secure that his bright lines are of a *greater* breadth than the star spectrum when he uses no cylindrical lens, and of a *less* breadth than the star spectrum when he broadens it out into a band by the use of a cylindrical lens?* How is it that they escape the broadening effect of the cylindrical lens whilst the spectrum on which they stand is widened out? It was this point in particular which made me say (*Monthly Notices*, vol. xlvi. p. 283): "It seems very difficult to believe that this can be a description of the behaviour of true stellar bright lines," and not the changeable flickering appearance which Mr. Sherman ascribes to them, though I confess that, in my view, added to the unlikelihood of their being true lines. My remarks as to the positions of the slit and cylindrical lens were also directed to this point, as I thought it possible that with a slit badly adjusted and the cylindrical lens close to the eye, false images, produced within the spectroscope, might present the very appearance Mr. Sherman has described of long lines in the red, and stellar points in the green. Per-

* "At the red end, under a sharp focus, they (the bright lines) stand out the full breadth of the spectrum, bearing somewhat the same relation to the background as the prominence to the solar spectrum. *In the brighter portion of the spectrum they are cut down to fine star-points.*"

sonally I much prefer the use of the cylindrical lens before the slit, but it is not *necessarily* wrong to use it close to the eye.

Mr. Sherman, whilst expanding my criticism as to the width of his slit, fails to see how it affects his measures. His slit was 6′ of arc in width, the diffraction disc of his star was, he adds, about 3″. The slit was therefore 120 times too wide at least, not merely 100 times, as I said. The purpose of a slit in stellar spectroscopy is twofold. It is not necessary in order to see the spectrum, but it is necessary to give it purity, and so to bring up fine lines. And it is absolutely essential for measures of position. Unless the slit is so nearly closed as just to hold the star between its jaws, what guarantee has the observer that the star is not travelling about from one side to the other of the slit? And if the star moves, the lines in its spectrum will move too. With a slit of the width recorded by Mr. Sherman no reliance whatsoever can be placed on the positions he records for the lines he observed, unless he can show that he had some means of absolutely fixing the star to one particular and invariable position. Then again, how did he obtain his fiducial points for the reduction of his observations? Did he allow the light from vacuum tube or taper to shine in through this wide slit, thus practically observing the comparison spectrum through a slit 120 times that of the stellar spectrum? Surely I was right in saying that such a slit was practically no slit at all. Mr. Sherman, for all that appears, might as well have removed his slit plates altogether.

I infer from the second paragraph on p. 18 in Mr. Sherman's reply that he wishes to withdraw his claim for some, if not for many, of the stars he has examined. I felt sure that more careful and continued observations would lead him to that conclusion.

Finally, I have no wish to say that in every case Mr. Sherman has been misled. I frankly confess that I do not think his observations look promising; but since we were both in pretty close accord as to our observations of *Nova Andromedæ*, he will, I hope, acquit me of any desire to pass a sweeping condemnation on his entire work.

With regard to the numerous quotations he has made from various observers, I trust that he will not do me the injustice of supposing that they were either unknown to or ignored by me. I do not, however, see how they bear upon the point at issue, which is, not whether bright lines have not been detected in a few special stellar spectra, but whether they form a prominent but hitherto unsuspected feature in every one of fifty stellar spectra taken at random; and whether true bright lines could behave as Mr. Sherman has described his lines as doing, viz. show themselves either as broader or narrower than the general stellar spectrum of which they formed a part.

Royal Observatory, Greenwich:
1886, *December* 10.

Observations of Comet f 1886 (*Barnard*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of Declination.

Comet f 1886.

1886.	Greenwich Mean Solar Time. h m s	Observer.	☄−★ R.A. m s	Corr. for Par. and Refract. in R.A. s	☄−★ N.P.D. ′ ″	Corr. for Par. and Refract. in N.P.D.	No. of Comp.	Apparent R.A. h m s	Apparent N.P.D. ° ′ ″	Comp. Star.
Nov. 17	18 0 31	T.	+0 40·00	−0·24	+ 8 24·5	−6·1	2	13 11 48·72	77 6 50·5	*a*
17	18 1 30		−0 29·70	−0·25	− 2 22·5	−6·5	1	13 11 50·29	77 6 23 3	*b*
18	17 5 26	H. T.	−3 32·85	−0·29	− 1 5·6	−6·3	6	13 18 35·82	76 41 14·9	*c*
30	17 25 57		+1 25·00	−0·40	+ 7 21·4	−6·6	3	15 7 23·80	72 17 52·0	*d*
30	17 48 7		+5 7·43	−0·40	− 2 28·8	−7·5	3	15 7 33·93	72 17 26·6	*e*
Dec. 2	17 55 49		−0 52·66	−0·40	+ 4 11·0	−7·1	8	15 29 30·29	72 1 55·4	*f*
7	5 29 34	T.	+0 38·15	+0·40	− 4 39·5	−7·8	4	6 19 45·65	72 17 2·1	*g*
7	5 34 45		−0 33·81	+0·50	− 8 36·8	−8·4	10	16 19 47·89	72 17 11·4	*h*
9	17 5 3	H. T.	+0 21·73	−0·30	+11 36·5	−4·7	3	16 47 9·83	72 57 5·5	*i*

Mean Places of Comparison Stars.

Star's Name.	R.A. 1886·0.			N.P.D. 1886·0.			Authority.
	h	m	s	°	′	″	
a W.B. XIII. 151	13	11	8·05	76	58	22·9	Weisse's Bessel
b W.B. XIII. 171	13	12	19·33	77	8	43·3	„ „
c W.B. XIII. 325	13	22	8·08	76	42	18·1	Glasgow Catalogue
d W.B. (2) XV. 80	15	5	57·60	72	10	33·6	Weisse's Bessel (2)
e W.B. (2) XIV. 1323–4	15	2	26·25	72	19	59·0	„ „
f τ^3 Serpentis	15	30	22·76	71	57	49·7	Greenwich 9-year Catalogue
g W.B. (2) XVI. 532–3	16	19	6·49	72	21	51·4	Weisse's Bessel
h W.B. (2) XVI. 563	16	20	20·53	72	25	58·6	„ „
i W.B. (2) XVI. 1419	16	46	57·77	72	45	38·0	„ „

Notes.

The observations are corrected for parallax and refraction. The initials H. T. and T. are those of Mr. Turner and Mr. Thackeray respectively.

Royal Observatory, Greenwich:
1886, *December* 10.

Observations of Comet Winnecke 1886, *made at Sydney Observatory with the* 11½ *Equatorial and filar micrometer.*

(*Communicated by H. C. Russell, B.A., Government Astronomer.*)

Date 1886.	Sydney M.T.	Star's Name.	Comparison Stars. R.A.	N.P.D.	Diff. of Comet from Star. R.A.	N.P.D.	Comet's position.		No. of Comp.
	h m s		h m s	o ′ ″	m s	′ ″	h m s	o ′ ″	
Sept. 2	7 39 18	25809 Lalande			− 0 27·32	+ 10 8·62			10
7	7 23 13	4777 B.A.C.	14 19 7·81	102 50 10·98	− 0 51·30	+ 2 36·99	14 18 16·51	102 52 47·97	3
8	7 35 32	5955 Wash. Gen. Cat.	14 19 13·38	103 34 15·01	+ 3 26·80	+ 2 4·53	14 22 40·18	103 36 19·54	5
10	7 30 53	26481 Lalande			+ 6 29·75	− 4 9·45			2
11	7 35 33	*27606 Lalande	14 34 15·19	105 42 58·56	+ 1 52·34	+ 3 41·27	14 36 7·53	105 46 39·83	10
14	7 16 3	27033 Lalande			+ 4 39·38	+ 4 22·73			10
15	7 31 24	27272 Lalande			+ 1 44·25	− 9 22·96			10
16	7 45 33	8261 Cape Cat. '80	15 5 44·70	109 21 33·39	− 5 45·51	+ 4 12·89	14 59 59·19	109 25 46·28	8
17	7 28 40	27567 Lalande			+ 1 37·38	+ 3 57·65			10
18	7 25 34	6282 Wash. Gen. Cat.	15 12 10·60	110 41 11·47	− 2 10·40	+ 11 11·86	15 10 0·20	110 52 23·33	10
20	8 16 17	27980 Lalande			+ 4 29·51	− 9 28·14			7
20	8 57 44	†8301 Cape Cat. '80	15 9 47·92	111 58 36·84	+ 10 58·20	+ 22 44·99	15 20 46·12	112 21 21·83	2
21	7 28 3	28282 Lalande			− 0 49·25	− 3 27·84			10
22	8 15 8	8516 Cape Cat. '80	15 33 32·92	113 26 46·68	− 2 12·66	+ 18 59·32	15 31 20·26	113 45 46·00	5
23	7 34 18	8559 Cape Cat. '80	15 39 4·33	114 21 21·40	− 2 21·18	+ 4 19·70	15 36 43·15	114 25 41·10	10
24	7 39 11	8628 Cape Cat. '80	15 46 47·47	114 59 7·31	− 4 27·83	+ 8 7·86	15 42 19·64	115 7 15·17	10
25	7 33 52	8676 Cape Cat. '80	15 51 58·84	115 47 4·66	− 3 58·30	+ 0 48·59	15 48 0·54	115 47 53·25	3
28	7 34 9	8807 Cape Cat. '80	16 5 18·41	117 37 44·10	+ 0 18·16	+ 8 42·33	16 36·57	117 46 26·43	10
29	7 31 2	8857 Cape Cat. '80	16 11 15·17	118 19 43·86	+ 0 23·19	+ 4 28·67	16 11 38·36	118 24 12·53	10

* This star was observed with the Sydney Transit Instrument on June 25, 1886.

† The difference between the comet and an 8½ mag. star first observed, then the difference between the 8½ mag. star and 8301 Cape Cat. '80.

1886, Sept. 1.—Comet seen; only approximate position obtained.

Sept. 2.—Comet very faint as close to moon; a diffused coma, no decided nucleus.

Sept. 8.—Strong moonlight; comet much more condensed than on Sept. 2. Coma small, about $\frac{1}{4}'$ in diam.

Sept. 9.—Comet much brighter even with increased moonlight; a suspicion of a nucleus. Observed with a star not in catalogue.

Sept. 10.—Comet extremely faint, and difficult to observe owing to haze.

Sept. 14.—Comet brighter; a suspicion of a nucleus.

Sept. 15.—Comet much brighter; coma about 1′ in diam.

Sept. 20.—Comet brighter; condensed in the centre, with a very faint nucleus.

Sept. 21.—Comet bright, but no very distinct nucleus, but condensed in the centre. At $8^h\ 2^m\ 13^s$ S.M.T. the centre of the comet passed over a 9-mag. star. The star did not diminish in brightness, but appeared to have a slight haze round it. Three other 9-mag. stars in the field. A very faint nucleus was thought to be seen in glimpses; but if there at all it must be very faint.

Sept. 22.—Comet not so bright as last night. Difference of declination determined by the circle.

Sept. 24.—Night particularly bad; comet much fainter than it has been. A glimpse of a nucleus.

Sept. 25.—Evening very hazy; haze stopped further observations.

Sept. 28.—Comet faint; coma diffused, with a faint nucleus.

Sept. 29.—Comet fainter.

Telescope 11½-inch Equatorial, with filar micrometer.

Observations of Comet discovered by Finlay at the Cape, Sept. 26, 1886, *made at Sydney Observatory with the* 11½*-inch Equatorial and filar micrometer.*

(*Communicated by H. C. Russell, B.A., Government Astronomer.*)

Date. 1886.	Sydney M.T.	Star's Name.	Difference of Comet from Star. Comet—Star. R.A.	Comet—Star. N.P.D.	No. of Comp.
	h m s		m s	′ ″	
Sept. 30	10 0 53	9391 Cape Cat. '80	+1 45·7	− 7 44·51	1
Oct. 1	8 48 47	9391 Cape Cat. '80	+4 10·9	− 5 11·66	5
5	8 26 0	9504 Cape Cat. '80	+4 12 70	+13 40·92	6
11	9 17 49	9766 Cape Cat. '80	−7 51·28	− 7 52·87	4
12	8 2 21	9766 Cape Cat. '80	−4 57·38	− 6 59·78	10

Sept. 30.—Comet faint.

Oct. 5.—Moonlight; comet faint.

Oct. 7.—Comet observed with a star not in catalogue.

Oct. 8.—Comet brighter. At beginning of observations comet in a straight line with two 9-mag. stars. Change in R.A. during evening very apparent. Observed with a star not in catalogue.

Oct. 11.—Evening very hazy; comet very faint.

Oct. 12.—Comet faint.

On Evidence with respect to the Form of the Area in the Heavens from which the Meteors of November 27, 1885, appeared to Radiate. By A. C. Ranyard.

There were a great many observers of this rich shower, and most of them seem to agree that the meteors did not radiate from a point, but that there was a radiant area of some considerable extent. I did not observe the shower till well after its maximum at nearly nine o'clock; but from the forty or fifty meteors whose paths I observed, and was able to trace back upon the heavens (making a mental estimate of the distance of the radiant, judged from the length of the path and velocity), I thought that the area from which they radiated was elliptical, with its major axis nearly north and south, some 12° or 15° long, and a minor axis of 6° or 8°. I mentioned the elliptic shape of the area I had observed to Col. Tupman, and he told me that in the chart of paths he had laid down the radiant area was distinctly elliptical. But as I did not see any reason for such an elliptic form of the area, I regarded the coincidence as merely accidental, and thought that our results were probably not founded on a sufficient number of observed tracks. When Col. Tupman described his observations at the evening meeting of the Society, he stated that the longer axis of the elliptic area observed by him lay north and south. This struck me as an additional coincidence, for I felt sure that I had not mentioned to him the direction of the axes of the elliptic area observed by me; but I did not think seriously of the matter till a few weeks after, when I saw a letter from Prof. Young in *Nature* of December 17, in which, after describing his observations, he says that "the radiant was not a point but rather a region about 4° long north and south, and 2° wide." I then wrote to ask Prof. Young further about his observation, and he replied that the radiant region was "an oval area," perhaps a little larger than he had at first estimated.

Recently during a visit to the observatory at Nice, M. Perrotin showed me a map on which he and his assistants had laid down the courses of sixty or seventy meteors they had observed on the night of November 27. I at once saw that the paths did not radiate from a point, and without telling M. Perrotin of the other observations, I asked him to draw a contour line round the area of radiation. Both he and M. Thollon, who was present, drew elliptic curves with the longer axis north and south, or rather inclined 10° or 15° to the west of the north point.

The accompanying woodcut is made from the contour lines laid down by M. Perrotin and M. Thollon on a tracing from their map.

There therefore appears to be some very definite evidence that the paths of these meteors *did* radiate from an elongated area with its axis north and south. I have been thinking over the possible physical causes of such an elliptic area of radiation. If the paths of the meteors were all parallel they would appear to meet in a point. And if, on entering the earth's atmosphere, they were deflected from their original direction, and there was no greater tendency to deflection in one direction than in another, they would, on becoming luminous, move in paths which would be symmetrically arranged with respect to the original direction of motion, and an observer would refer them to a circular area of radiation with its centre corresponding to the original direction of motion outside the earth's atmosphere. If there were a greater tendency to scattering or "skidding" from the original direction of motion on entering the atmosphere in one direction rather than in the direction at right angles, the area of radiation would be elongated in the heavens in a direction corresponding with the direction of greatest "skidding." The elliptic area of radiation of the Biela meteors shows that their paths, at all events after they become luminous within the earth's atmosphere,

are not parallel, and that there is a greater tendency to deviate from the mean direction to the north and south than to the east and west.

It has been suggested by those who, like Sir Stawell Ball and Mr. Proctor, are inclined to believe that meteors were originally projected from the earth, that if they were ejected in slightly different directions they would not return moving in parallel paths; but if their paths outside the earth's atmosphere were not parallel, their orbits and their periods would be so very different that they would not come up to the earth again in a single swarm. We may therefore, I think, assume that the paths of the different components of a meteoric swarm are parallel in space before they encounter the earth's atmosphere, and that they are deflected by reason of their irregular shapes after they enter the earth's atmosphere, and usually before they become luminous, though there is abundant evidence that such deflection or "skidding" from their original course sometimes takes place after they become luminous. Professor Newton, Col. Tupman, and Mr. B. J. Hopkins have recorded meteors with curved paths. I have, on two occasions, seen meteors with curved paths, and there is a meteor with a very decidedly curved path in the chart of meteor tracks observed at Greenwich on the night of November 27, 1885, which is given at p. 62 of the December number of the *Monthly Notices* for 1885.

In order to account for the elliptic area, on the assumption that the deflection from the original path takes place within the earth's atmosphere, it is necessary to find some cause which would account for the deflection being greater in one plane than in the direction at right angles to it. This would be the case if there were some arrangement of the particles in space which caused them to set themselves with their longer axes north and south. I would suggest that if the particles are magnetic they would, on coming up to the earth, tend to arrange themselves with their longer axes parallel to the earth's magnetic axis. And in connection with this it is worth noticing that the axis of the contours drawn by M. Perrotin and M. Thollon do not point to the North Pole, but some 12° or 14° to the west of north, which about corresponds to the deviation of the magnetic meridian at Nice.

Neither Mr. Nash at Greenwich, who seems to have laid down with great care the tracks he gives in his chart, "principally from observations made between 8^h and 9^h 30^m," nor Mr. Denning, whose attention was attracted by the large area of radiation, seem to have noticed its elliptic shape. But with such slow-moving meteors as those of the Biela swarm, the elliptic shape of the area above referred to would probably be missed by observers who combined tracks laid down with an interval of three or four hours. For, owing to the axial rotation of the earth, the centre of radiation would appear to shift rapidly in the heavens in a direction nearly at right angles to the longer axis of the observed

ellipse. Thus, by combining observations separated by a sufficient interval of time, a circular area of radiation might be deduced, though the true area of radiation for any instant was an ellipse of considerable ellipticity.

Mr. Denning appears to think that the radiant area of this shower was larger than that usually observed. He says:—"In many cases I found that very accurately observed paths deviated several degrees from the mean. The area of radiation must have been fully 7° in diameter to accommodate the discordances in the flights. The centre was at 24°+44°; but I saw several very short paths from a point south of *γ Andromedæ*." This would seem to indicate that the radiant area was elongated in a north-westerly direction. Mr. Denning adds:—"I noted many of the meteors with the utmost care, in order to assure myself of the diffuseness of radiation, and it was found impossible to get a sharply defined position. The contrary effect was indeed so obvious as to arrest the eye whenever simultaneous bursts of about six or seven meteors took place near the radiant. It was then seen that the collective flights were not symmetrical emanations from a central point. They rather appeared to be discharged in a loose, disjointed fashion, from a comparatively large space on the N.W. region of *γ Andromedæ*, and just perhaps enveloping the star within its limits."

If the great extent of the radiant area should turn out to be peculiar to this shower, it would be evidence that the meteoric particles of the Biela stream are more irregular in shape than those of other streams. For example, one can conceive that they might be elongated crystalline forms, or a sponge-like meshwork of crystals containing magnetic iron, which has been torn into more than usually irregular shapes; or the irregular forms may be due to exposure to heat, which has evaporated volatile substances from the interstices of crystals with a higher melting point.

The size and shape of the area of radiation is well worthy of careful examination during future showers, noting the corresponding star magnitude of the meteor, observed beside each track laid down. Since the mass of similar-shaped meteoric particles varies as the cube of their diameter, while their resisting surface varies as the square of the diameter, we may expect to find the smaller particles heated to incandescence on entering the atmosphere more rapidly, and in a higher region, than larger masses, and the forces tending to deflect them from their original course bearing a larger proportion to the momentum the smaller the particle. It is probable that only the larger particles which enter the atmosphere become visible as naked-eye meteors, the dust-like particles being lost as telescopic meteors, or with a sudden spark, which, owing to distance and atmospheric absorption, may not be visible even as a telescopic meteor.

Some idea as to the size of meteoric particles capable of giving the light of a sixth-magnitude star may be derived from the

consideration that a standard candle, seen at the distance of a mile, is only a little brighter than a first-magnitude star. Consequently, without taking atmospheric absorption into account, an incandescent body at a distance of 100 miles would only appear as a sixth-magnitude star if it shone with a light about equal to that of an electric lamp of 100 candles power. As only the larger meteors enter the earth's atmosphere to a depth of below 70 miles above the surface, it may be assumed that few of the meteors seen, except those which appear in the zenith, approach within 100 miles of the observer. One may, consequently, pretty safely assume that a meteor which is just visible to the naked eye is larger than the portion of the carbons which is rendered incandescent in an arc-light of 100 candles power. For a mass of carbon such as is used for electric lighting purposes gives off more light while being driven into vapour than other substances which have been experimented upon; and the carbon of the electric light is not exposed to the tremendous bombardment of cold air, which must tend greatly to accelerate the disintegration of the meteoric particles in their passage through the air, as well as to cool their surface by removing the incandescent matter as rapidly as it is formed. If the above reasoning is correct, a much greater amount of matter must enter the Earth's atmosphere during a meteoric shower than has hitherto been supposed. Such matter would in time find its way to the Earth's surface, and when we consider geological periods of time, would have a sensible effect on the growth of the Earth, and the shape of continents.

Note on an Erratic Meteor. By B. J. Hopkins.

In November 1885 I had the honour of reading before the Society a Paper, containing a series of observations of mine of a class of meteors which from the apparent form of their paths I termed "erratic." I pointed out in that Paper that the appearance of these bodies was comparatively rare, and in proof of that statement I may here remark that, in a correspondence on the subject which I had with Mr. Denning, he informed me that, though he had observed considerably over 1,300 meteors during the year 1885, only four of them described paths similar to those mentioned in my Paper above referred to.

On account of their being so rarely seen, I have thought that a few remarks upon one I had the good fortune to observe on December 4, 18 hrs., would not be without interest; particularly as the meteor presented not only the peculiarity of a wavy path, but also had that path broken in two. The meteor referred to was of a brilliant white colour, and equalled *Jupiter* in apparent magnitude; it made its appearance near *ν Ursæ Majoris*, and disappeared between *ι Draconis* and *γ Ursæ Minoris*.

The first portion of its flight extended from the point of its appearance to just beyond *ζ Ursæ Majoris*, where it made a slight curve, the convex side of the curve being towards that star; at this point the train of light following the meteor in its flight divided, and the remainder of its path was continued at a short distance (about 30′) above the level—if I may use such a term—of the path pursued by it at its first appearance, though parallel to it. I have on one or two previous occasions noticed breaks in the path of a meteor, but never took any particular notice of it, looking upon it as merely an optical illusion; or the phenomenon has been so slight that I have not been able to decide whether I had actually seen it, or if it was due to fancy. Such an appearance as I have tried to describe would be caused, for instance, if at the point of disappearance of a meteor another made its appearance, and so as it were continued the path of the first. But in this case, owing to the brightness and slow motion of the meteor (it was visible for two seconds), and to the fact that I was looking at the part of the heavens in which it appeared at the moment it did so, thus having it in view from first to last, I can most confidently affirm that it was not an illusion due to the cause just mentioned, or to the imagination.

Diagram of Erratic and broken-pathed Meteor, 1886, Dec. 4.

A suggestion put forward, I believe, by Mr. Ranyard, during the discussion which followed the reading of my former Paper, viz., that the irregular shape of some meteors is the reason of their describing curved paths, will probably account for the slight curve I observed in the path of this meteor. But it is not so easy to explain the break in the path. Mr. Denning has observed meteors with divided paths, and accounts for them by ascribing the appearance as due to variations in the light of the meteor; this meteor did not, however, vary in brightness, and differed from those observed by Mr. Denning in that the second portion of its path was not in a line with the first. Whatever caused the meteor to change its course seems also to have been the cause of the momentary disappearance of the meteor, and it is in hopes of some explanation of the phenomenon being forthcoming that I venture to bring this observation before the notice of the Society.

Forest Gate, E.:
1886, *December* 9.

Ephemeris of the Satellites of Uranus, 1887. By A. Marth.

P, angle of position of the minor axes of the apparent orbits.

a, *b*, major and minor semi-axes of the apparent orbits.

$u - U$, longitudes of the satellites in their orbits, reckoned from the points which are in superior conjunction with the planet or in opposition to the Earth.

$U + 180°$, planetocentric longitude of the Earth reckoned in the assumed plane of the orbits from the ascending node on the celestial equator.

B, planetocentric latitude of the Earth above the plane of the orbits, the ascending node N and inclination T in reference to the equator of 1880·0 are assumed to have the values

$$N = 165°{\cdot}770 \qquad T = 75°{\cdot}210$$

The corresponding values in reference to the plane of the orbit of *Uranus* are: long. of node 166°·005, inclination 98°·017, the long. of the node being reckoned along the planet's orbit from the point which precedes the ascending node of the planet's orbit on the ecliptic by its ecliptical longitude.

		Ariel.				*Umbriel.*			
Greenwich Noon.		P	a_1	b_1	$u_1 - U$	Diff.	a_2	b_2	$u_2 - U$	Diff.
1887.		°	″	″	°	°	″	″	°	°
Jan.	13	284·388	14·62	+ 6·42	346·06	1428·49	20·31	+ 8·94	189·78	868·77
	23	·392	14·72	6·47	334·55	·46	20·50	9·02	338·55	·74
Feb.	2	·409	14·84	6·50	323·01	·43	20·68	9·06	127·29	·72
	12	·438	14·96	6·51	311·44	·40	20·84	9·07	276·01	·70
	22	·477	15·06	6·49	299·84	·37	20·98	9·04	64·71	·67
Mar.	4	·524	15·14	6·45	288·21	·35	21·10	8·98	213·38	·66
	14	·575	15·20	6·38	276·56	·32	21·18	8·89	2·04	·64
	24	·627	15·24	6·30	264·88	·29	21·23	8·77	150·68	·62
Apr.	3	284·679	15·24	+ 6·19	253·17	·27	21·24	+ 8·63	299·30	·61
	13	·729	15·22	6·08	241·44	·25	21·21	8·48	87·91	·61
	23	·774	15·18	5·97	229·69	·24	21·15	8·32	236·52	·59
May	3	·813	15·11	5·86	217·93	·23	21·05	8·16	25·11	·60
	13	·844	15·02	5·75	206·16	·22	20·93	8·01	173·71	·59
	23	·866	14·92	5·65	194·38	·22	20·78	7·87	322·30	·60
June	2	·880	14·80	5·57	182·60	·22	20·61	7·76	110·90	·60
	12	·885	14·67	5·50	170·82	1428·23	20·44	7·67	259·50	868·62
	22	284·881	14·54	+ 5·46	159·05		20·25	+ 7·60	48·12	

		Titania.				*Oberon.*				
		a_3	b_3	u_3-U	Diff.	a_4	b_4	u_4-U	U	B
1887.		″	″	°	°	″	″	°	°	°
Jan.	13	33·32	+ 14·66	155·68	413·54	44·56	+ 19·61	116·88	2·483	+ 26·109
	23	33·63	14·79	209·22	·53	44·97	19·78	24·29	2·492	26·098
Feb.	2	33·92	14·86	262·75	·51	45·36	19·88	291·69	2·515	25·989
	12	34·19	14·88	316·26	·49	45·72	19·90	199·07	2·552	25·797
	22	34·42	14·83	9·75	·48	46·03	19·84	106·43	2·601	25·530
Mar.	4	34·60	14·73	63·23	·46	46·28	19·70	13·78	2·659	25·199
	14	34·74	14·58	116·69	·45	46·46	19·50	281·12	2·724	24·818
	24	34·82	14·38	170·14	·45	46·56	19·24	188·45	2·792	24·405
Apr.	3	34·83	+ 14·15	223·59	·44	46·58	+ 18·93	95·78	2·861	+ 23·978
	13	34·79	13·90	277·03	·44	46·52	18·59	3·10	2·927	23·557
	23	34·69	13·64	330·47	·44	46·39	18·24	270·43	2·988	23·159
May	3	34·53	13·38	23·91	·45	46·18	17·89	177·76	3·040	22·801
	13	34·33	13·14	77·36	·45	45·90	17·57	85·09	3·083	22·498
	23	34·08	12·91	130·81	·46	45·58	17·27	352·44	3·114	22·262
June	2	33·81	12·72	184·27	·47	45·22	17·02	259·79	3·132	22·103
	12	33·52	12·57	237·74	413·48	44·83	16·81	167·16	3·136	22·027
	22	33·22	+ 12·47	291·22		44·43	+ 16·67	74·53	3·127	+ 22·038

The values of P, a, b and u–U are to be interpolated directly for the times for which the apparent positions are required, the equation of light being already taken into account. The position-angles p and distances s are then found by means of the equations

$$s \sin (p-\mathrm{P}) = a \sin (u-\mathrm{U}),$$
$$s \cos (p-\mathrm{P}) = b \cos (u-\mathrm{U}).$$

The satellites move in the direction of increasing position-angles, and will be at their greatest elongations and at their conjunctions with the centre of the planet at the following hours, Greenwich mean time :—

Ariel.

	N. Elong.	S. Elong.		N. Elong.	S. Elong.		N. Elong.	S. Elong.
p=	P+90°	P−90°		h	h		h	h
1887	h	h	Mar.	10 4·2	11 10·4	April	16 23·5	18 5·8
Feb. 2	21·3	4 3·6		12 16·6	13 22·9		19 12·0	20 18·3
5	9·8	6 16·1		15 5·1	16 11·4		22 0·5	23 6·8
7	22·3	9 4·6		17 17·6	18 23·9		24 13·0	25 19·3
10	10·8	11 17·0		20 6·1	21 12·4		27 1·5	28 7·8
12	23·3	14 5·5		22 18·6	24 0·9		29 14·0	30 20·3

$p=$	N. Elong. P+90°		S. Elong. P−90°	
1887	h		h	
Feb.	15	11·8	16	18·0
	18	0·3	19	6·5
	20	12·7	21	19·0
	23	1·2	24	7·5
	25	13 7	26	20·0
	28	2·2	M. 1	8·4
Mar.	2	14·7	3	20·9
	5	3·2	6	9·4
	7	15·7	8	21·9
Mar.	25	7·1	26	13·4
	27	19·6	29	1·8
	30	8·1	31	14·3
April	1	20·6	3	2·8
	4	9·1	5	15·3
	6	21·6	8	3·8
	9	10·1	10	16·3
	11	12·6	13	4·8
	14	11·0	15	17·3
May	2	2·5	3	8·7
	4	15·0	5	21·2
	7	3·5	8	9·7
	9	16·0	10	22·2
	12	4·5	13	10 7
	14	17·0	15	23·2
	17	5·5	18	11·7
	19	18·0	21	0·2
	22	6·5	23	12·7

Umbriel.

Feb.	1	13·7	3	15·4	Mar.	10	20·8	12	22·6	April	17	4·0	19	5·8
	5	17·2	7	18·9		15	0·3	17	2·0		21	7·5	23	9·3
	9	20·6	11	22·3		19	3·8	21	5·5		25	11·0	27	12·7
	14	0·1	16	1·8		23	7·2	25	9·0		29	14·5	M. 1	16·2
	18	3·5	20	5·3		27	10·7	29	12·4	May	3	17·9	5	19·7
	22	7·0	24	8·7		31	14·2	A. 2	15·9		7	21·4	9	23·1
	26	10·4	28	12·2	April	4	17·6	6	19·4		12	0·9	14	2·6
Mar.	2	13·9	4	15·6		8	21·1	10	22·8		16	4·3	18	6·1
	6	17·4	8	19·1		13	0·6	15	2·3		20	7·8	22	9·5

Titania.

$p=$	Super. Conj. P		N. Elong. P+90°		Infer. Conj. P−180°		S. Elong. P−90°	
	h		h		h		h	
Jan.	26	15·5	Jan. 28	19·7	Jan. 31	0·0	Feb. 2	4·2
Feb.	4	8·4	Feb. 6	12·7	Feb. 8	16·9	10	21·2
	13	1·4	15	5·6	17	9·9	19	14·1
	21	18·3	23	22·6	26	2·8	28	7·1
Mar.	2	11·3	Mar. 4	15·5	Mar. 6	19·8	Mar. 9	0·0
	11	4·3	13	8·5	15	12·7	17	17·0
	19	21·2	22	1·5	24	5·7	26	10·0
	28	14·2	30	18·5	April 1	22·7	April 4	2·9
April	6	7·2	April 8	11·4	10	15·7	12	19·9
	15	0·2	17	4·4	19	8·6	21	12·9
	23	17·1	25	21·4	28	1·6	30	5·9
May	2	10·1	May 4	14·4	May 6	18·6	May 8	22·8
	11	3·1	13	7·3	15	11·6	17	15·8
	19	20·1	22	0·3	24	4·6	26	8·8
	28	13·0	30	17·3	June 1	21·5	June 4	1·8

Oberon.

p=	Super. Conj. P		N. Elong. P+90°		Infer. Conj. P−180°		S. Elong. P−90°	
1887		h		h		h		h
Jan.	22	2·2	Jan. 25	11·0	Jan. 28	19·7	Feb. 1	4·5
Feb.	4	13·3	Feb. 7	22·1	Feb. 11	6·9	14	15·7
	18	0·5	21	9·2	24	18·0	28	2·8
Mar.	3	11·6	Mar. 6	20·4	Mar. 10	5·2	Mar. 13	14·0
	16	22·8	20	7·6	23	16·4	27	1·2
	30	10·0	April 2	18·8	April 6	3·6	April 0	12·4
April	12	21·2	16	6·0	19	14·8	22	23·6
	26	8·4	29	17·2	May 3	2·0	May 6	10·8
May	9	19·6	May 13	4·4	16	13·2	19	22·0
	23	6·8	26	15·6	30	0·4	June 2	9·2

Titania and *Oberon* will appear in the same direction from the centre of the planet February 3, $23^h{\cdot}5$; February 28, $14^h{\cdot}8$; March 25, $6^h{\cdot}1$; April 18, $21^h{\cdot}4$; May 13, $12^h{\cdot}7$; June 7, $4^h{\cdot}1$; and in opposite directions February 16, $7^h{\cdot}2$; March 12, $22^h{\cdot}4$; April 6, $13^h{\cdot}7$; May 1, $5^h{\cdot}0$; May 25, $20^h{\cdot}4$.

Erratum, vol. xlvii. p. 9, 3rd line from bottom :—

for $\frac{e^4}{3}$ sin 2M, *read* $\frac{e^4}{3}$ sin 2M.